Amendments to the claims of the International Application under PCT Article 19 filed with IB of WIPO

1. "I claim" is replaced by "We claim"

2. Claims 1 to 12 unchanged; Claims 13 and 14 amended; new claim 15 added.

10/069364
JC18 Rec'd PCT/PTO 25 FEB 2002

CLAIMES

We claim:

1. An MIMO (multiple-input multiple-output) PID controller which has

- an n-dimensional process variable vector PV with the n process variables PV1, PV2, …, and PVn being its first, second, …, and n-th component,
- an n-dimensional set point vector SP with the n set points SP1, SP2, …, and SPn being its first, second, …, and n-th component, and
- an m-dimensional controller output vector CO with the m controller outputs CO1, CO2, …, and COm being its first, second, …, and m-th component,

where m and n are positive integers, and in which the PID control equation is CO(k) = CO(k-1) + K1*SP(k)*T + K1*a(k,1) + K2*a(k,2) + … + Kj*a(k,j), where k is the discrete time, T is the sampling period, j is a positive integer, K1, K2, …, Kj are m by n PID parameters, a(k,1) = [-PV(k)]*T, and a(k,j) = [a(k,j-1) – a(k-1,j-1)]/T for j > or = 2.

2. An MIMO PID controller of Claim 1, in which the m by n PID parameters K1, K2, …, and Kj are obtained by using an optimization algorithm which minimizes the largest modulus of all poles of the discrete time closed loop transfer function from said SP to said PV.

3. An MIMO PID controller of Claim 2, wherein the said optimization algorithm is a constrained optimization algorithm which minimizes the largest modulus of all poles of the discrete time closed loop transfer function from said SP to said PV and at the same time guarantees that the user prescribed constraints on the PID parameters are satisfied

4. An MIMO PID controller of Claim 1, wherein some or all of the terms K2*a(k,2), K3*a(k,3), …, and Kj*a(k,j) that appear on the right-hand side of the PID control

equation are removed, for example, a PID controller with its control equation being $CO(k) = CO(k-1) + K1*SP(k)*T + K1*a(k,1) = CO(k-1) + K1*[SP(k)-PV(k)]*T$, which is also called a I-only controller, and a PID controller with its control equation being $CO(k) = CO(k-1) + K1*SP(k)*T + K1*a(k,1) + K2*a(k,2) = CO(k-1) + K1*[SP(k)-PV(k)]*T - K2*[PV(k)-PV(k-1)]$, which is also called a PI controller, etc.

5: An MIMO PID controller of Claim 4, wherein the remaining PID parameters are obtained by using an optimization algorithm which minimizes the largest modulus of all poles of the discrete time closed loop transfer function from said SP to said PV.

6: An MIMO PID controller of Claim 5, wherein the said optimization algorithm is a constrained optimization algorithm which minimizes the largest modulus of all poles of the discrete time closed loop transfer function from said SP to said PV and at the same time guarantees that the user prescribed constraints on the PID parameters are satisfied

7. A PID controller of Claim 1, wherein said PV, said SP, said CO, and said PID parameters are all scalars, and m=n=1.

8: A PID controller of Claim 2, wherein said PV, said SP, said CO, and said PID parameters are all scalars, and m=n=1.

9. A PID controller of Claim 3, wherein said PV, said SP, said CO, and said PID parameters are all scalars, and m=n=1.

10. A PID controller of Claim 4, wherein said PV, said SP, said CO, and said PID parameters are all scalars, and m=n=1.

11: A PID controller of Claim 5, wherein said PV, said SP, said CO, and said PID parameters are all scalars, and m=n=1.

12: A PID controller of Claim 6, wherein said PV, said SP, said CO, and said PID parameters are all scalars, and m=n=1.

13. A method of finding the optimal PID parameters for any traditional independent or dependent form of PID controllers by using a qualified minimax algorithm that minimizes the largest modulus of all poles of the discrete time closed loop transfer function from set point SP to process variable PV.

14· A method of Claim 13, wherein the minimax algorithm is a constrained minimax algorithm which minimizes the largest modulus of the discrete time closed loop transfer function from said SP to said PV and at the same time guarantees that all PID parameters are within their admissible ranges.

15. A PID controller of Claim 1, 4, 7, or any traditional PID controller, wherein the PID parameters are obtained using an optimization method such that

(1) the maximum real part of all poles of the continuous-time closed-loop transfer function from said SP to said PV is minimized, subject to any user specified constraints on the PID parameters, such as some or all elements in the PID parameters should be within user specified ranges, or

(2) the maximum magnitude of some or all elements in the PID parameters is minimized, subject to the constraint that the maximum real part of all poles of the said continuous-time closed-loop transfer function from said SP to said PV is not larger than a user specified number.

13 (amended): A method of finding the optimal PID parameters or tuning constants for any PID controller or a linear controller by minimizing the largest modulus of all poles of the discrete time closed loop transfer function from set point SP to process variable PV.

14 (amended). A method of Claim 13, wherein the optimal PID parameters or tuning constants are obtained by minimizing the largest modulus of the discrete time closed loop transfer function from said SP to said PV subject to the constraint that some or all of the PID parameters or tuning constants are within user specified admissible ranges.

15 (amended): A PID controller of Claim 1, or any PID controller or linear controller, wherein the PID parameters or tuning constants are obtained such that

(1) the maximum real part of all poles of the continuous-time closed-loop transfer function from said SP to said PV is minimized, possibly subject to any user specified constraints on the PID parameters or tuning constants, such as some or all of elements in the PID parameters or tuning constants should be within user specified ranges, where the said PID parameters or tuning constants can be matrices or scalars, or

(2) the maximum magnitude of some or all elements in the PID parameters or tuning constants is minimized, subject to the constraint that the maximum real part of all poles of the said continuous-time closed-loop transfer function from said SP to said PV is not larger than a user specified number.

13 (amended) A method of finding the optimal PID parameters or tuning constants for any [traditional independent or dependent form of PID controllers] PID controller or a linear controller by [using a qualified minimax algorithm that minimizes] minimizing the largest modulus of all poles of the discrete time closed loop transfer function from set point SP to process variable PV.

14 (amended) A method of Claim 13, wherein [the minimax algorithm is a constrained minimax algorithm which minimizes] the optimal PID parameters or tuning constants are obtained by minimizing the largest modulus of the discrete time closed loop transfer function from said SP to said PV [and at the same time guarantees] subject to the constraint that some or all of the PID parameters or tuning constants are within [their] user specified admissible ranges.

15 (amended) A PID controller of Claim 1, [4, 7,] or any [traditional] PID controller or linear controller, wherein the PID parameters or tuning constants are obtained [using an optimization method] such that

(1) the maximum real part of all poles of the continuous-time closed-loop transfer function from said SP to said PV is minimized, possibly subject to any user specified constraints on the PID parameters or tuning constants, such as some or all of elements in the PID parameters or tuning constants should be within user specified ranges, where the said PID parameters or tuning constants can be matrices or scalars, or

(2) the maximum magnitude of some or all elements in the PID parameters or tuning constants is minimized, subject to the constraint that the maximum real part of all poles of the said continuous-time closed-loop transfer function from said SP to said PV is not larger than a user specified number.